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Author(s): Karl T. Compton

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## SCIENCE IN AN AMERICAN PROGRAM FOR SOCIAL PROGRESS

By Dr. KARL T. COMPTON

PRESIDENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE rôle which science has played in social progress is nowhere more succinctly set forth than in the preamble to resolutions adopted by the American Association for the Advancement of Science, and submitted to the President of the United States in December, 1934:

WHEREAS, Development and application of science have been basic to the economic and social progress of nations, making possible such movements as universal education, abolition of child labor and slavery, emancipation of women, insurance and pensions, moderate hours of labor and great improvement in the standards of health, comfort and satisfaction in living; and

WHEREAS, Scientific developments have not only conferred general benefits, but in particular have been largely effective in leading to recovery from previous depressions—as the railroad industry following the depression of 1870, the electric industry following that of 1896, and the automobile industry following that of 1907; and

WHEREAS, Scientific research is a productive investment proven by experience to yield a high rate of return, as illustrated by the saving of \$2,000,000,000 per year from the Bessemer steel process and of over \$1,000,000 per day from the modern incandescent lamp, and as illustrated also by the entire chemical, electrical, communication, transportation and metallurgical industries and by the enormous employment in such industries;

That our national health, prosperity, pleasure, and indeed our very existence, depend largely upon science for their

maintenance and their future development, no informed person would deny. Within our generation this truth has been emphasized, for we have come to the end of free expansion by migration westward, and of free exploitation of ever newly discovered resources of soil and minerals. We have reached the point beyond which further increase in our wealth, population, physical comfort and cultural opportunity will depend not on discovering new resources by geographical exploration but by wiser use of the resources that we now have, through scientific exploration.

This idea is not new, but I doubt if we realize its profound significance; it marks a turning point in the history of the world! How did the Egyptians, the Greeks and the Romans secure their wealth? By plunder and taxation of conquered nations and by "labor-saving" production through the work of enslaved peoples. How were the great commerce and wealth of England acquired? Through geographical exploration, conquest and colonization of virgin lands with such returns in wealth as we find it hard now to comprehend. For example, the profits of the British East India Company were of the order of 100 per cent. on each voyage of its merchantmen.

Now all livable portions of the world are settled and closely interconnected by travel and trade. Probably the Italian conquest of Ethiopia and Japan's expansions into China are about the ending of the centuries old struggle for wealth through territorial conquest. In our own country, Horace Greeley's advice "Go west, young man, go west" no longer has its original significance. The geographical pioneer is now supplanted by the scientific pioneer, whose thrill of discovery or urge for reward is no less keen and whose fields of exploration are probably unlimited. Without the scientific pioneer our civilization would stand still and our spirit would stagnate; with him mankind will continue to work toward his higher destiny. This being so, our problem is to make science as effective an element as possible in our American program for social progress.

Practically all scientific work in the United States is carried on under one or another of three auspices—the government, industrial organizations, and educational institutions or similar altruistic foundations. The scientific services of the Federal Government are spread through forty bureaus, of which eighteen are primarily scientific. There are about 630 colleges and universities in the United States, including 155 engineering schools. There are upwards of 1,600 research laboratories operated by industrial companies. Watson Davis, of Science Service, recently estimated the total annual national expenditure in scientific research work as about \$100,000,000, divided roughly equally between government, educational institutions and industry. Each of these three categories of scientific work has its proper scope, limitations and opportunities. Each has its peculiar problems of operation. I will proceed, therefore, to discuss them separately.

#### SCIENCE IN GOVERNMENT

During the two and a half years of its existence, terminating last December, I had the extraordinary opportunity to serve as chairman of the Science Advisory Board, under which, with its subcommittees, more than a hundred of the country's ablest scientists and engineers gave free and devoted service to the scientific interests of the government at the request of the President. Out of this experience I could draw a kaleidoscopic picture of the scientific work of the government: work of vast importance to the welfare of the country; staffed by an army of able scientists single-mindedly devoted to their respective jobs; financed by less than half of one per cent. of the total governmental budget; replete with duplicating and uncoordinated effort; subject to the charge that many projects are started, but few are ever stopped; with partisan loyalties to bureaus and departments continually blocking attempts at changes in organization even when there is no disagreement as to the improved efficiency that would thereby be gained; with almost no executive officers, more permanent than the current administration, to coordinate the various bureaus, direct their programs and plan their future; yet with sincere and often courageous concern on the part of department secretaries for the efficient working of the bureaus under their jurisdictions; and under all these conditions a surprisingly effective service; these are some of the facets of this kaleidoscopic picture. (In these remarks I except the two military departments, which are organized on a more permanent basis.)

This is not the occasion to discuss the specific problems which were referred to the Science Advisory Board, which were technical problems of organization, scientific programs, budgets or personnel. Suffice it to say that there was generally

good cooperation from high officials from the President down and that there was much actual accomplishment, reflected in the present and pending operations of a number of the scientific bureaus, despite regrettable failure to achieve results in some important matters. But of greater significance than these specific jobs was the development in the minds of the board of a certain conception of the rôle of the government in science which I can not present better than by quoting certain passages from the final report of the Science Advisory Board to the President:

An absolute prerequisite to (our national) welfare, independent of political theories and basic to attempts at national planning or improvement of any kind or degree, is adequate scientific information regarding the materials and forces with which great groups of our population have to deal. This is the justification for the existence of scientific bureaus in the Government.

In a democracy like ours, designed to safeguard personal liberty and to stimulate individual initiative within the framework of "general welfare," there is no need for the Government to embark upon comprehensive programs in pure science, invention or industrial development. There are, however, numerous scientific services of such wide scope and universal utility that no agency except the Government is competent adequately to handle them. (In this category are public health, weather forecasting, topographic mapping, development of scientific and technical standards, mineral surveys and statistics, safety codes, patents, soil science, improvement of crops and live stock.) There are other scientific services which are essentially supplementary to non-scientific governmental activities. (Among these are engineering work relating to flood control, water supply and aids to navigation; scientific aids to national defense; development of standards for the purchasing of supplies for use of governmental bureaus.) There are also fields of scientific or technical development which hold evident promise of benefiting the public but which are not proper or practical fields for private initiative (such as the activities of the National Advisory Committee for Aeronautics, and the financial aid to land grant colleges for development of agriculture and engineering arts). In

these three categories and in this order of importance lie the proper scientific activities of the Government.

The first scientific bureaus to be established had to concern themselves but little with the coordination of their programs. Each filled a definite need and its purpose was to gather facts in a designated field. (These federal services, however, have expanded enormously with the increasingly complex demands of our civilization.) Side by side with the growth in the number of bureaus and in the multiplicity of their functions, there should have been applied (more rigorously) the principle of coordination of related work, no matter in what bureaus the work may be done. (This is a primary requisite for efficiency.)

Freedom of scientific work from political or policy-making influences is a second prime consideration. Whatever the trend of social or political thought and whatever the degree of national planning, the people of the country have the right to expect that the scientific services are always free to report and interpret the facts in a given field of inquiry as they find them and not as the government of the day may wish to have them reported or interpreted. (They) should be free to produce results that are not discolored by the opinions and snap judgments of policy-making political groups who may wish to put the dignity of "science" behind their plans in order to win public approval.

Over and above the work of particular scientific bureaus, there is increasing activity on the part of the Government in undertaking large projects whose feasibility or justification are matters for technical decision from many points of view: scientific, economic, humanitarian. Examples of such projects are: irrigation, power development, flood control, soil erosion control, shelter belt, waterways, retirement of sub-marginal land and colonization. Where huge sums are involved and large groups of people affected, it is more than ever necessary that decisions and policies should be settled only after the most thorough, competent and disinterested study of such questions as: Is the project technically feasible? Will it accomplish its purpose? What are the alternatives, and has the best plan been selected? Will the benefits justify the expenditure? For technical advice on such questions, Congress and the Executive Departments should have ready access to, and should use, the best talent available both within and outside of the government services.

It is (therefore) the concern of every citizen that there be available to government the most competent and impartial advice which can be

found. The endurance of our traditional form of government will depend in increasing measure upon the quality of expert judgment, tempered with experience, which is available to government, and the willingness of government to follow such judgment.

Considerations like these led the Science Advisory Board to recommend to the President the permanent establishment of a scientific advisory council, its members to be nominated by the National Academy of Sciences and to serve without pay, but with provision for necessary travel and secretarial expenses. This council would be enabled to appoint subcommittees on the principal scientific bureaus. The duties of this group would consist, first, in assisting the bureau chiefs to formulate general programs and policies; second, in promoting coordination and working against improper duplication of effort of the various bureaus; third, in interpreting, criticizing or defending the work and plans of the bureaus before the responsible department secretaries and congressional committees; fourth, in giving to the director of the budget its critical and independent judgment, (advisory only), regarding budgets and requests for appropriations for scientific work in the non-military departments.

It is my conviction, shared by my engineering and scientific colleagues who have studied the situation during the past three years, that some such plan would be feasible, and that it would do more to increase the efficiency and the prestige of the federal scientific services than can be achieved in any other way. It may be that thought of such an independent and sometimes critical advisory service is not relished by any official who is more concerned with maintaining his unlimited authority than with ensuring efficient conduct of the people's business for which he is responsible. But when I heard a high official say that "of course the plan is impractical," I thought to

myself that this only means that he and some of his colleagues do not like it. Plans similar to the one here proposed have been in successful operation in several European countries in recent years. In Great Britain, for example, a group of the Empire's greatest scientists act as official advisers to the privy council on all questions of programs and budgets for scientific work under governmental auspices.

#### SCIENCE IN INDUSTRY

Turning now to industry, we have no difficulty in defining its proper scope of scientific research: that type of research is justified which shows reasonable promise of producing better products or desirable new products which can be made and sold with profit or of reducing the cost of existing products. Within this simple definition, however, lies great scope for informed judgment, courage and skill in the decision as to "what constitutes reasonable promise?" and "how great is this promise in comparison with the probable cost?" It is the action on such questions that largely determines the future growth or decay of an industry.

Experience has convinced progressive industries that as much as several per cent. of income can profitably be spent on research. This expenditure is both an investment for future dividends and an insurance against future loss through obsolescence or more enlightened competition. Dr. Robert A. Millikan emphasized the investment aspect when he said: "Research pays because you know what you want, go after it with informed brains by the scientific method, and in general get it: But it often yields (extra) dividends because you get something more that you didn't go after." And Francis Bacon, over three hundred years ago, described the fate of the industry which neglects research when he wrote: "That which man altereth not for the

better, Time, the Great Innovator, alter-eth for the worse." The statement is not unusual which was made a few years ago by the president of a great manufacturing company when he told his stockholders that 60 per cent. of sales that year had been of products that ten years before were unknown.

Several years ago the National Research Council compared the financial health of industries, as a function of their activity in research, as measured, for example, by relative expenditures for research. At the top were such industries as the chemical, electrical, communications and automotive; toward the bottom were railroads, lumber and textiles. The correlation between support of research and financial prosperity was decidedly striking and has been an effective object lesson.

In any attempt to make science more effective in industry and through it more helpful to the public, certain obstacles must be met and overcome.

First I would mention the so-called "hard-headed practical business man"; a man without vision, imagination or enthusiasm for new things; a man who scoffs at theory or a college degree; a man whose sole criterion of proper practice is that which he has been accustomed to in the past; a man who spends as little as he can on research in order that his profits day by day may be larger. The withering policies of such men have driven many a flourishing business into obsolescence. If, by accident, a research laboratory has been set up in this man's company, its staff will be among the first to be fired in a depression, thus saving temporarily dollars but losing permanently the capital investment in trained intelligence.

In this same class I would place that type of control, sometimes exercised by a financial group, which focusses attention on the profits of the current year

to practical exclusion of developing strength for the future. I see many examples of this, in which the organization has become so weakened by the time it sees its mistake that it has not the strength to embark on a different course, and therefore continues to become sicker and sicker. One species of this type of business anemia arises when the cost accountant becomes the master instead of the servant—applying cut-and-dried methods of evaluation, on a monthly or yearly basis without discrimination and without realizing the values which may reside in a research, a big idea or an active brain.

From these two examples, which I have purposely stated strongly, you may infer that I advocate the growing tendency to give technically trained men an increasing share in the management and policy-making activities of industry—and I do not mean to infer that financially trained men are not also essential.

A second obstacle is the cost, delay and uncertainty in the operation of our out-moded patent procedures. This is one of the major hindrances to the development of new industries and the supplying of new employment through the results of science. It is greatly to be hoped that favorable action will be taken by Congress on several recommendations by the Science Advisory Board aimed at increasing the presumptive validity of patents and the accuracy and ease of decisions by the courts.

A third obstacle is found in the increasing regulatory activities of the government for the stated objective of protecting the public, but sometimes in the nature of disastrous boomerangs. I believe that an increasing degree of regulation of business for protection of the public is a necessary accompaniment of increasing general complexity and competition. But this regulation should be benevolent and intelligent, two charac-

teristics which are not as prevalent as they should be. A fundamental difficulty appears to reside in the fact that in general we are governed by politicians rather than by statesmen. By this I mean that our elected rulers are generally men of alert perception to public opinion, nimble in debate, persuasive in oratory and skilful in dealing with group psychology; but these excellent qualities do not necessarily fit them to make wise decisions in such questions as: What technical procedure of subsidies, or curtailed planting, or research to create new industrial uses for his products, will best help the farmer and at the same time the country as a whole? or, Is a public utility company justified in charging on its bills to to-day's customers part of the cost of research designed to improve or cheapen the service of to-morrow's customers? These are profound questions, which greatly affect the ability of science to promote our social welfare. Our present method of deciding such questions is frequently expensive, illogical or ludicrous and is sometimes disastrous. However, while recognizing this difficulty, I can offer no solution to it and am unable to prove that we do not have the best of all possible types of governments in the best of all possible worlds, in the long run. Thus I will mention the government no more, except to point out that its present attitude toward both industry and science is in unflattering contrast with that of several European countries which have helped industry in a positive way by offering it definite incentives to embark upon a more active program of scientific and industrial research, considering this to be a national investment for future prosperity and employment.

#### SCIENCE IN EDUCATIONAL INSTITUTIONS

In educational institutions, science has no limitations in search for truth except

those imposed by availability of ideas, workers, facilities and funds. Such institutions have always been the places where the great bulk of new discoveries are made and ideas born, and this will continue to be so, since there exist no other organizations where such studies can be similarly pursued. The practical aims of educational institutions in science are well described by Dr. Isaiah Bowman: "The trade school exists for the admirable purpose of putting practically trained men into jobs; the university exists, among other things, to create and expand the sciences that provide the jobs. It is in engineering that these two points of view are effectively joined."

The fact that the universities and engineering schools do feed industry with most of the new ideas, which industry then transforms into products of social value, was illustrated by Dr. Roger Adams in his recent presidential address before the American Chemical Society when he said, "The basic and fundamental information for over 95 per cent. of the industrial processes has been originally discovered and described by the university investigator." I recall a statement written by Herbert Hoover, when he was Secretary of Commerce, in which he expressed concern lest the industrial supremacy of America should be lost because our industrial leaders were not actively enough concerned with laying the foundations for the industrial future by strongly supporting pure scientific work at the present time. Mr. Hoover not only believed this, but he worked to bring about increased support of pure science by industry until the presidency brought him new and greater problems.

Growth of industry and employment and gain in civilization through science are like the growth of plants in nature: of many seeds which are scattered, only

a few grow to be vigorous plants; but if no seeds were produced and scattered there would be no plants at all. Scientific discoveries are the seeds of industry and public welfare, and the universities are the nurseries in which they are produced and nurtured to the point where some of them can be transplanted into the fields of industry. I once likened new industries to babies—they need shelter and nourishment, which they take in the form of patent protection and financing. But, before all, they need to be born, and their parents are science and invention. Neither laws nor committees nor juggling acts nor wishful thinking can perform the first necessary step of conception. To maintain and advance our civilization we need more and better scientific seeds and industrial babies. The educational institutions of higher learning are the birthplaces of this new knowledge, as well as the training and proving grounds for the young men and women who will carry this knowledge on and put it to practical use.

In discussing this matter with my friend, Dr. Charles F. Kettering, he expressed the opinion that one of the major problems of both industry and the universities is to facilitate this production and nurture of the seeds of industrial progress, in the universities, and to narrow the gap and hazard between discovery and successfully launched business. To do this requires closer cooperation between industry and educational institutions, involving more active research programs in the institutions, their more generous financial support by industry or by the captains of industry, and closer personal contacts between the men in the two groups who have related interests.

My own observations of what can be accomplished in an educational institution like the one which I represent convince me that there are really great op-

portunities along these lines. I have seen the sprouting of literally hundreds of promising ideas; I have seen the cooperative effort of professorial chemists, physicists, electrical engineers and metallurgists solve serious industrial problems that had baffled the skilled practical men of industry; I have seen a little of the desired financial support; and I have seen productive mutual stimulation in such cooperation. As I see it, a great university or engineering school already possesses, because of its teaching responsibilities, the principal overhead of staff, facilities and administrative organization necessary for a large research program, so that relatively large returns in the fields of research and development can be secured with relatively little additional financial support. It is in this direction that there lies, in my judgment, the greatest opportunity for increased contributions to public welfare through science in the leading educational institutions, and thus far the surface has only been scratched. I believe that, with more adequate financial support, a new order of institutional public service will be possible.

One peculiarity of scientific research is that its results can usually not be foreseen, for if they could be foretold they would not be new. Also, when a new discovery is made, it is not usually immediately obvious as to the possibilities of its practical uses. And again, the solution of a scientific problem may be a long, hard struggle—longer than was realized by a visitor who asked Harvard's President Conant what he was doing in his laboratory. When Conant replied, "We are seeking to discover the chemical formula for chlorophyl," his visitor exclaimed, "Why, how is that? You were working on that problem when I was here last year!"

Because of these uncertainties I can not predict just what the next big sci-

entific developments will be, but I can assure you that they will come and that they will be important. Among the fields that seem to me to show especial promise are: development of new industrial uses for farm products; improvements in transmission and utilization of electric power; great developments in materials and methods of building construction; increased range and precision of weather forecasting; conquest of hitherto unconquered diseases, both physical and mental; better regulation of bodily functions; a new era in biological discovery operating with the tools of physics, chemistry and engineering; a similar new era in physical science centered around atomic nuclear transformations; and so on, the field is literally limitless.

Having thus suggested a few of the more significant ways in which science may be made to contribute more effec-

tively to the American program for social progress, through the agencies of government, industry and education, I close by saying that the greatest of all contributions of science is not to be found in the comforts, pleasures or profits which flow from it, but in the freedom and imagination which it has brought to the human spirit and the sense of relationship and unity in the world. Of all descriptions of the true spirit of science I like best the words of the ancient Greek philosopher, Aristotle, which appear engraved on the beautiful home of the National Academy of Sciences in Washington: "Search for truth is in one way hard and in another way easy, for it is evident that no one can master it fully nor miss it wholly, but each adds a little to our knowledge of Nature, and from all the facts assembled there arises a certain grandeur."